1

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THE POTASSIUM-ARGON AGE OF THE BOSUMTWI CRATER IN GHANA AND THE CHEMICAL COMPOSITION OF ITS GLASSES

~~ABSTRACT~~

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ABSTRACT

Two glasses from the Bosumtwi crater in Ghana which we collected during an excursion had been dated by potassium argon measurements. The glass from the Buonim river shows an age of $1.2 \pm 0.1 \times 10^6$ y, which may be slightly lowered because of diffusion loss. The glass from the valley of the Ata river shows an age of $1.4 \pm 0.2 \times 10^6$ y. It possibly is somewhat increased by inherited argon. The average value for the age of the crater therefore is $1.3 \pm 0.3 \times 10^6$ y. This value is in good agreement with the potassium argon age of the Ivory Coast tektites ($1.3 \pm 0.2 \times 10^6$ y, Zähringer 1962). By these experiments the common origin of Bosumtwi crater and the Ivory Coast tektites has been experimentally founded for the first time.

The chemical major and minor constituents of these two glasses and a tektite specimen from the Ivory Coast have been determined by X-ray-fluorescence technique and compared among each other. They yielded considerable chemical similarities, above all for the minor elements, abundances of which are much more characteristic than those of the major constituents. The K/Zr, Rb/Zr, Ni/Fe and Cr/Ni ratios are also similar for these three samples and are important arguments in the discussion on the origin of Ivory Coast tektites.

Abstract

The origin of these glasses seems to be the same as described in an earlier paper about the glasses of the Nördlinger Ries and the Moldavites. In both cases a meteorite impact could be the source of these glasses.

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In the West-African state of Ghana, an almost circular crater the Bosumtwi Crater, with a diameter of 13 kilometers, containing a lake, lies about 300 kilometers inland. The origin of this formation has posed a puzzle for geologists similar to that of the Nördlinger Ries in Southern Germany. Tectonic subsidence, volcanic erruption and the impact of a giant meteorite have been considered as possible mechanisms of its origin. An indication for the last hypothesis are "arenaceous manifestations and compression sutures" (Rohleder 1936) and the occurrence of "coesite" in pumiceous glass formation (Littler et al 1961). Althogh the Bosumtwi Crater lies in very old pre-Cambrian (more than 1.7×10^9 years) rock, the well-preserved form of the Crater, possible glacial-age terrace formations, deposits of fossil fishes, and its isolated location in relation to the general fluvial system of the country indicate that the Crater originated during the early tertiary and perhaps even pleistocene era.

Tuff and breccia as consequences of the crater formation contain glassy pumiceous components which can be dated with the potassium-argon method. Two known places of such finds are in the valleys of the Ata and of the Buonim River. The Geological Survey of Ghana made available to us a piece of "suevite" from Ata from its collection. We isolated from this 500 mg. of green glass and obtained its age as not over or less than 5.5×10^6 years. More exact determination was not possible because no further material was available for control. An overestimation of this age through hidden contamination of the glass by the very old surrounding rock and by the content of the gas bubbles in this glass could not be definitely excluded.

We were successful in rediscovering, together with Professor Th. Monod (Dakar) and A.F.I. Smith (Legon), the original locations of these finds and to obtain specimens. The first specimen consisted of a large block of a grey rock shown to be glassy lying in the water of the Buonim River. The second specimen was from a breccial rock out cropping in the Ata River bed, with small glassy inclusions with millimeter to centimeter dimensions. Professor Frechen (Bonn) examined polished sections of these rocks. The Buonim specimen is a porous, colorless to grey-brown glass which is probably slightly metamorphized. The pigmentation may have been caused by minute secondary limonite formation. A finely distributed argillaceous deposit on the pore walls is responsible for the slight greenish coloration of the glass. Feldspat is occasionally and quartz frequently included. The Ata specimen represents well-preserved glass of greenish color, contains bubbles and is in part foamy. The parent breccia contains many rock fragments of high age including phyllite and mica schist with much biotite, muscovite, quartz and lime epidote.

The Buonim specimen basically was a homogeneous glass. It was crushed by us from which we screened three fractions and these were dated separately in order to exclude the possible content of bubbles as source of error. However, the Ata specimen had a large size spectrum since the glass grains were easily destroyed during removal from the parent rock. We screened out three fractions also for this. Those with the largest grains (of millimeter dimensions) were then sorted out under the microscope in order to prevent any contamination by adhering old rock. From the thus selected glass, we sorted out the dark glass splinters with few bubbles and the light ones containing many bubbles. The dark glass has a higher specific weight than the light glass which is probably due to the bubbles.

The two concentrates were dated separately, i.e. in the original grain classification of 1 to 3 mm. in grains 0.2. mm. in dimension and as powder (50 to 70 micron). Nearly all bubbles had been broken open in this powder. The potassium content was determined by flame-photometry. We base the indications of age on the constants for potassium decay lambda= 5.32×10^{-10} a^{-1} and $lambda_k$/ $lambda_{beta}$ = 0.123. The findings are listed in the attached table 1. The ages indicated are mean values of not less than two measurements in each case.

The three grain sizes of the Buonim specimen resulted in almost the same age of 1.2 +/ -0.1 x 10^6 years. However, the Ata specimens produced a different age for each grain classification. The greatest age resulted from the non-crushed grains of millimeter dimensions, i.e. 2.7 x 10^6 years for the light and 2.2 x 10^6 years for the dark glass. The medium grain classification indicated an age of 1.7 adn/or 1.5 x 10^6 years. The powder had an age of 1.7 and/or 1.4 x 10^6 years. The explanation of this apparent trend of age with grain classification stems from the bubbles. We crushed one specimen each under vacuum in order to analyze the bubble content and found an argon content of the bubbles for the Ata specimens of over 1 x $10^{-6}cm^3/g$ with a small amount of excess $argon^{40}$ (2 to 3 %). The high values of the large grains containing bubbles thus become understandable. The medium grain classification contains only few bubbles and consequently less atmospheric argon and therefore indicates a lesser age. The measured atmospheric argon content of the powder is again higher because the adsorbing surface becomes larger through pulverization. The potassium-argon age of the powder is probably closest to the true age. There remains the question why the value for the light is 20 % higher than for the dark glass. It is possible that originally included argon still exists in the light glass where the many bubbles indicate less advanced degassing. Since a slight increase may exist for this reason also in the dark glass, we assume the value of 1.4 x 10^6 years as upper limit and the age of the Ata specimens as less or equal to 1.4 x 10^6 years. The dating of the Ata glass given to us by the Geologic Survey of Ghana probably resulted as too high due to the bubbles and contamination with extraneous rock.

The potassium-argon age of the Buonim specimen is probably too low. We concluded this from microscopically recognizable changes and from a diffusion experiment made with this glass. At room temperature, diffusion constants of 10^{-18} to 10^{-19} cm^2/sec and an activation energy of only 22 kcal/mol resulted. Consequently, diffusion losses since formation of the glass must be taken into consideration. We can therefore only say that the age of the Buonim glass is greater or equal to 1.2x10^6 years.

However, the Ata and Buonim glasses both originated simultaneously during the formation of the Crater. We therefore indicate with these two ages limits of the interval of time within which the Bosumtwi Crater was formed. In consideration of the experimental error, this interval amounts to 1. 1 to 1.6 x 10^6 years. If we gave the same weight to the dating of the powdered light Ata glass, the interval would increase to 1.7 x 10^6 years. By taking into account all these possibilities of error, the Bosumtwi Crater has an age of 1.3+/-0.3 x 10^6 years. From recent concepts of the early Tertiary time scale, the time found indicates the middle to lower Pleistocene and agrees with the geological findings.

The potassium-argon age of the Ivory-Coast tektites as indicated by Zähringer (1962) amounts to 1.3 +/-0.2 x 10^6 years. Within the limits of error, the tektites of the Ivory Coast and of the Bosumtwi Crater consequently have the same age. A causal connection between these tektites and the crater, have the same age. A causal connection between these tektites and the crater, interpreted already in 1931 as meteorite crater by by Maclaren and desiganated as origin of the Ivory-Coast tektites by Cohen (1961), is therefore possible and has found an experimental confirmation for the first time by our measurementes.

Due to the dissimilarity of age, we thought it important to compare the chemical composition of the Ata and Buonim glasses with that of an Ivory-Coast tektite from Oulle (No.107 of our own collection) with particular consideration of the trace elements. The analyses were carried out with the roentgen-fluorescence method.

The chemical composition of a bubble-containing and of a black glass from the Bosumtwi Lake was determined for the first time in 1937 by H. and W. H. Bennett. Our analyses showed that the main components of the Ata and Buonim glasses are similar to that of the bubble-containing glass (1937) and minor variations were interpreted by us as variations due to the respective location of the finds.

The analysis of our Ivory-Coast specimen corresponds approximately to the mean value of the three Ivory-Coast tektites examined by Raoult (1934).The Ata glass and our tektite are very similar in their main components with the exception of calcium and sodium which are about twice as high in the Bosumtwi glass. However, the Buonim glass differs greatly in calcium and manganese contents which are appreciably lower in relation to the Ata glass and the tektite. In regard to the principal chemical components of the Bosumtwi glasses and the Ivory-Coast tektites, there exists therefore according to our findings an extensive concordance as shown also by the comparison made on the basis of earlier analyses by A. Cohen (1961).

Since the tektites are not characteristically different in the principal components and the investigation of the trace elements permits much more detailed statements on the chemistry during their creation, we list in the attached table 2 the values from analysis of the trace elements.

It is notable in these findings, that the absolute contents of chromium, nickel, copper, strontium and zirconium in the Bosumtwi glasses are strikingly similar and, with the exception of zirconium, are relatively high in relation to e.g. australites and bediasites. The nickel contents found are also appreciably higher (by a factor of approximately 5) in relation to moldavite and Ries glasses.

Ratios of various elements are shown in the lower part of table 2 which are intended to illustrate the separation of individual elements during the origin of the glasses. The potassium/zirconium ratio for Ata glass and the tektites is practically the same. It is appreciably higher than for the Buonim glass. Possible reasons for this will be indicated in the discussion of the rubidium/zirconium ratios.

Schüller and Ottemann (1963) found the rubidium/zirconium ratio to be a scale of classification for volcanic glasses, impact glasses and tektites by analysing 56 apecimens for rubidium and zirconium. The rubidium/zirconium ratio for acid volcanic glasses according to this lies between 2.8 and 0.8, for moldavites and Ries glasses between 0.8 and 0.45, for the Indo-Australian tektites between 0.45 and 0.25, and for the bediasites impact glasses and basic volcanic glasses below 0.25.

Table 2 shows that the rubidium/zirconium ratio determined by us amounts to 0.45 for Ata glass, 0.81 for Buonim glass and 0.39 for the tektite. The values for Ata glass and the tektites closely approach and are among the upper range of the limits for Indo-Australian tektites indicated by Schüller and Ottemann (1963). Both ratios are appreciably lower than the values for acid volcanic glasses. The values for the Buonim glass with 0.81 also lies lower than the latter but is appreciably higher than the other two. The reason for this might be sought in the different composition of the Ata and the Buonim glass. Since the Buonim specimen stems from a very large boulder, we assume that this block was fused uniformly but at lower temperatures than the Ata glass which exists only in small "drops". At lower temperatures, the evaporation of rubidium is less so that we can expect a higher rubidium content in the Buonim glass and a consequently higher rubidium/zirconium ratio.

Through activation analysis, Ehmann (1960, 1962) determined the nickel content of a number of tektites and other natural glasses and mainly discussed the nickel/iron ratio. He found values between 100 and 230 for definite impact glasses such as e.g.Henbury and Aouelloul, ratios between 5 and 57 for tektites and between 1.1 and 1.5 for three obsidian specimens (all values x 10^{-4}). He indicates a nickel/iron ratio of 22 x 10^{-4} for one Ivory-Coast tektite. Both the value for our tektite from this location (27 x 10^{-4}) as well as the ratios for the Ata (20 x 10^{-4}) and Buonim (18 x 10^{-4}) glasses concord rather well with this. Since all tektites, with the exception of those from Indonesia, Cambodia, and Annam, have nickel-iron ratios between 5 and 10 x 10^{-4}, the ratio of 20 x 10^{-4} for the Ivory-Coast tektites is very characteristic. That the nickel-iron ratios from the Ata and Buonim glasses also lie around this value is of decisive importance for the discussion of the origin of the Ivory-Coast tektites.

The chromium/nickel ratio shown in table 2 are very similar but lie lower than those indicated by Taylor (1962) for australite (2.65) and by Chao (1963) for bediasite (2.77).

Consequently, the findings from trace analysis also confirm a causal connection between Bosumtwi glasses and Ivory-Coast tektites which found its first experimental support by the concordance of potassium-argon age reported above.

In all these interrelations between Bosumtwi glasses and Ivory-Coast tektites, we are apparently confronted by a similar case as described earlier for the Nördlinger Ries and the moldavites (Gentner et al, 1962, Schüller et al 1963). In both cases, we can probably consider a similar extraordinary natural event, probably the impact of a meteorite, as cause.

A detailed report will be presented elsewhere together with Professor Th. Monod and A.F.I. Smit to whom we are indebted for the rediscovery of the glasses, and this will be accompanied by a detailed geological and minerological description.

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TABLE 1 -POTASSIUM-ARGON AGE DETERMINATION ON TWO GLASSES FROM THE BOSUMTWI CRATER IN GHANA

a.-SPECIMEN	b.-CLASIFICATION Ø in mm	Ar (total) $10^{-7} cm^3/g$	Ar %	(radiogen) $10^{-7} cm^3/g$	K %	c.-AGE 10^6 a	d.-REMARKS
	1	8,55	11	0,94	2,13	1,1 ± ,1	e.-NO POSSIBLE DIFFUSION LOSSES HAVE BEEN NOTICED HERE
	0,4	7,62	13	0,98	2,16	1,2 ± ,1	
	0,1	7,42	13	0,96	2,10	1,2 ± ,1	
f.-ATA LIGHT	1 - 3	12,8	13	1,67		2,7 ± ,3	g.- INCREASED AGE DUE TO ARGON IN BUBBLES
	0,1 - 0,3	3,98	27	1,06	1,57	1,7 ± ,1	
	0,05 - 0,07	5,29	21	1,09		1,7 ± ,2	
h.-ATA DARK	1 - 3	8,66	16	1,34		2,2 ± ,2	i.-INCREASED AGE DUE TO CONTENT OF BUBBLES
	0,3 - 0,5	3,17	30	1,04	1,53	1,7 ± ,2	
	0,1 - 0,3	2,60	35	0,90		1,5 ± ,1	k.-LESS EXCESS BECAUSE OF FEWER BUBBLES
	0,05 - 0,07	6,24	14	0,86		1,4 ± ,2	

l.-the mean values from not less than two measuremnts. The errors are the experimental errors of the argon and potassium determinations. In addition, a diffusion loss is possible for Buonim and a small contribution of originally occluded argon in the powdered "Ata dark".

m.- Age of Bosumtwi Crater $1,3 \pm 0,3 \times 10^6$ a.

TABLE 2.- Trace elements in Buonim glass, Ata glass and in an Ivory-Coast

Element	Glass Buonim ppm	Glass Ata ppm	Tektite ppm	
Cr	153	164	262	
Mn	253	652	541	
Ni	86	90	130	105 +
Cu	56	59	82	
Rb	127	73	64	
Sr	267	358	316	
Zr	156	164	163	
K/Zr	135	96	82	
Rb/Zr	0,81	0,45	0,39	
$(Ni/Fe) \times 10^{-4}$	18	20	27	22 +
Cr/Ni	1,78	1,82	2,02	

tektite. + nickel determination by activation analysis, Ehmannn (1960).

The relative error due to equipment and method is +/-5 %. In the element ratios indicated above, influences of the matrix are eliminated so that the relative error is +/-3 %.